

gonum trichopes Torr., *Chaenactis xantiana* Gray and *Salvia columbariae* Benth.

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ABNORMAL FRUITS AND SEEDS IN *ARCEUTHOBIMUM*¹

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The normal *Arceuthobium* fruit, as described in the literature (Thoday and Johnson 1930, Dowding 1931, Gill 1935, Kuijt 1955, 1960), consists of a single seed containing one embryo. This paper describes abnormal fruits with two seeds and seeds with two embryos and endosperms as found in some specimens of *A. americanum* Nutt. ex Engelm. and *A. vaginatum* f. *cryptopodum* (Engelm.) Gill.

The fruit of *Arceuthobium* and other members of the Loranthaceae differs from other angiosperms in that there are no true ovules. The ovarian cavity becomes nearly filled by an undifferentiated mound of tissue termed the mamelon, nipple, or ovarian papilla. Two embryo sacs are borne within the ovarian papilla. Usually only one embryo sac develops, but occasional diembryonic seeds have been reported in a number of species (Peirce 1905, Weir 1914, and Heinricher 1915). The process of fertilization in *Arceuthobium* has not been precisely described. However, the development of the embryo sac after fertilization is apparently similar to that in most dicotyledonous plants. As the fruit matures, the dominant embryo sac develops into a copious endosperm with a small embryo. The remnants of the ovarian papilla become crushed, and in *A. pusillum* they form a distinct "crest" at the base of the seed (Thoday and Johnson 1930). The crest was not well defined in the mature, normal *A. americanum* (fig. 1A) and *A. vaginatum* f. *cryptopodum* fruits examined. However, a small mass of tissue which is presumed to be analogous to the

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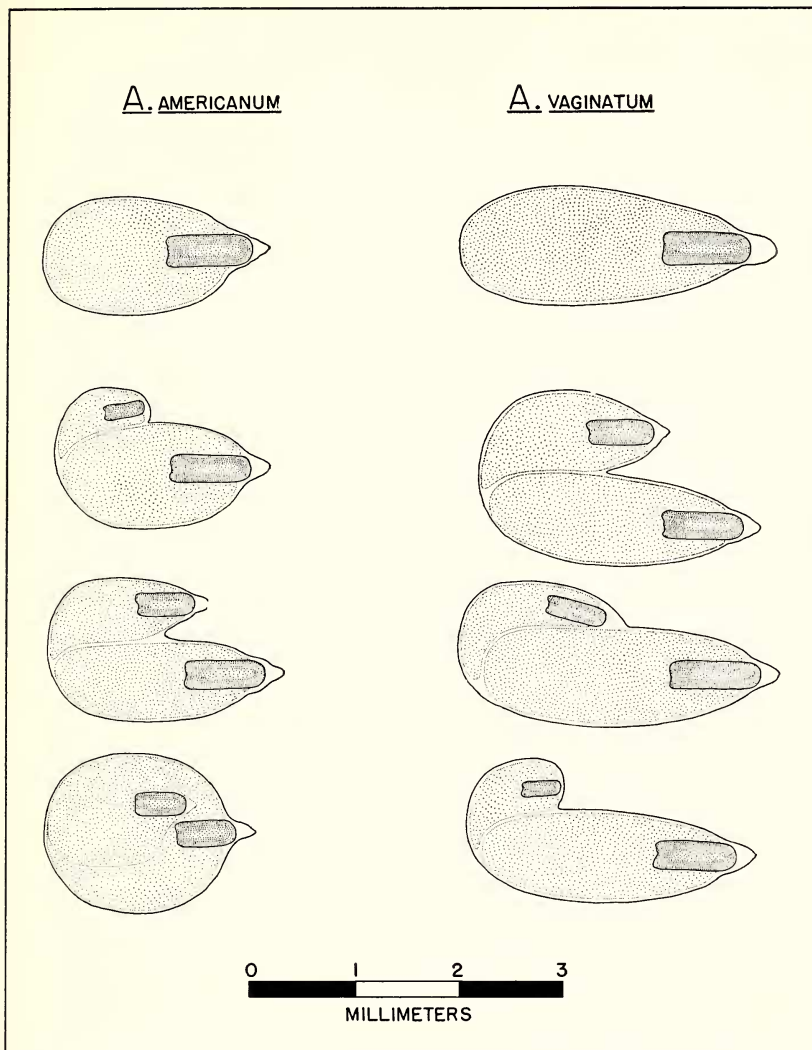


FIG. 1. Semi-diagrammatic drawings of longitudinal sections through *Arceuthobium americanum* fruits. A. Normal fruit with a single seed containing one embryo. The tissues labeled are: *v.c.*, viscin cells; *per.*, pericarp; *e.*, endocarp of the seed; *emb.*, embryo; *end.*, endosperm; *a.l.*, abscission layer; and *ped.*, pedicel. B-F. Abnormal fruits; these are described in the text.

crest in *A. pusillum* was observed in most fruits. At maturity the *Arceuthobium* fruit is severed from its pedicel, and the seed is forcibly ejected.

ABNORMAL FRUITS

Fruits of *A. americanum* with more than one stigma (figs. 1, 2) were noticed from plants in several areas of the Medicine Bow National Forest



FIG. 2. Fruits of *Arceuthobium americanum*: normal, D and H; abnormal, A-C, E-G. Scale below is millimeter rule.

in southern Wyoming and the Roosevelt National Forest in northern Colorado. In a sample of 803 fruits from one locality in the latter forest, seven, or 0.9 per cent, had two stigmas. Dissection of 16 abnormal fruits collected in August revealed four general types.

TYPE 1. Fruits with two stigmas and two normal seeds (fig. 1B; fig. 2F and 2G). A wall of tissue separating the two seeds was sometimes present (fig. 1F) and sometimes not (fig. 1B). Nine of the sixteen fruits dissected were of this type.

TYPE 2. Fruits with two stigmas, one normal seed and one aborted seed (fig. 1C and 1D; fig. 2A and 2C). Four specimens had a small aborted seed (fig. 1C), but only one was found with two full-sized chambers (fig. 1D).

TYPE 3. Fruit with one stigma but two normal seeds (fig. 1E; fig. 2B). Only one such fruit was found.

TYPE 4. Fruit with three stigmas and two normal seeds (fig. 1F; fig. 2E). One of the seeds had two embryos. Only one fruit of this type was found.

The abnormal fruits averaged about the same length as normal ones (3.6 mm.) but were about 50 per cent wider (2.7 compared with 1.9 mm.). The seeds from the multiple fruits measured 0.9 x 2.1 mm. compared with 1.0 x 2.2 mm. for seeds from normal fruits on the same plants.

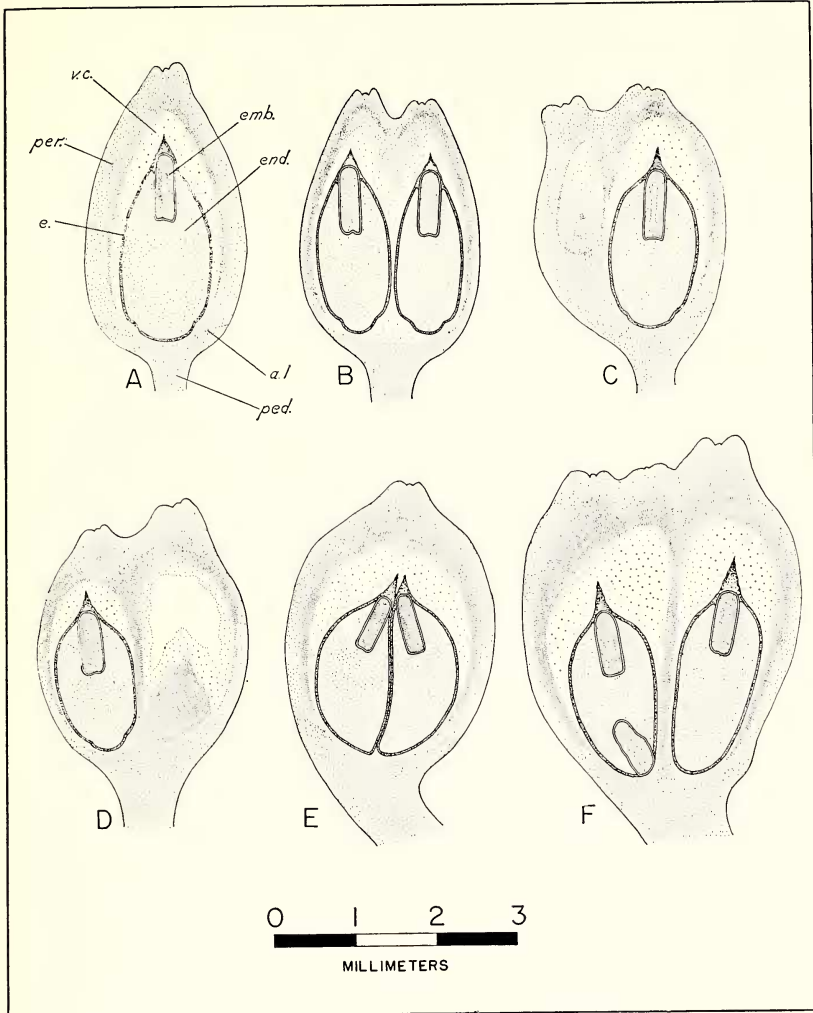


FIG. 3. Seeds of *Arceuthobium americanum* and *A. vaginatum* f. *cryptopodum*. The upper seed in each column is normal and of average size for the species. The lower three seeds in each column represent abnormal forms with two elements, each with an endosperm (light stippling) and embryo (dark stippling) within a common endocarp.

Intensive search yielded only one fruit of *A. vaginatum* f. *cryptopodum* with more than one stigma. This fruit, from near Estes Park, Colorado, had three stigmas and three distinct chambers. Two of these, the outer ones, contained normal seeds, but the central chamber had an apparently aborted seed (similar to that in the right chamber in fig. 1D).

Fruits with multiple stigmas have not been reported previously in *Arceuthobium*. Unfortunately, there has been no opportunity to observe

the development of these abnormal fruits. Possibly the double fruits arise as fasciations and each stigma is pollinated separately. The resulting seeds seem to develop more or less independently of each other. The two seeds are enclosed in separate endocarps.

Usually both seeds develop at about the same rate (type 1, fig. 1B), but sometimes one is suppressed (type 2, figs. 1C and 1D). I am unable to explain satisfactorily the development of the fruit bearing a single stigma but containing two normal seeds (type 3, fig. 1E); however, both embryo sacs may have developed as each seed became enclosed in a separate endocarp. The most unusual fruit was that containing three stigmas and two seeds, one with two embryos (type 4, fig. 1F). The diembryonic seed had embryos at opposite ends. Both embryos were about normal size, but the accessory one was somewhat irregular in shape.

ABNORMAL SEEDS

Peirce (1905) described a seed of *A. campylopodum* f. *campylopodum* (*A. occidentale*) that had two embryos (one about normal size and the other one third normal size) but within a single endosperm. Weir (1914) reported diembryonic seeds in *A. vaginatum* f. *cryptopodum* (3 of 20 seeds), *A. douglasii* (4 of 30 seeds), and *A. americanum*, and although he did not describe them in detail, he stated that they were morphologically similar to normal seeds but "occasionally below average size." Heinricher (1915, Plate 1, fig. 6) illustrated an unusual diembryonic seed in the European *A. oxycedri*; the seed itself appears to be similar to normal seeds, but it has two hypocotyls.

Diembryonic seeds have been found by the writer in both *A. americanum* and *A. vaginatum* f. *cryptopodum*. They differ from the diembryonic seeds previously described in the literature (see above) in that they also contain two endosperms (fig. 3). Apparently both embryo sacs develop so that there are two units each of embryo and endosperm, both enclosed within a common endocarp. (These differ from the seeds shown in fig. 1E which are enclosed in separate endocarps.) The two units differ in size, the embryo in the larger unit being about normal size. The embryo in the second unit is smaller, the reduction being approximately proportional to that of the endosperm. No seeds of this type were found in the abnormal fruits dissected, therefore it is assumed that they are formed in normal appearing fruits.

Counts of *Arceuthobium vaginatum* f. *cryptopodum* seeds in various localities showed that 1.0 per cent were of this abnormal type (Table 1).

No counts have been made on the frequency of abnormal seeds in *A. americanum*, but they appear to be about as rare as in *A. vaginatum* f. *cryptopodum*. It has not been determined whether or not these abnormal seeds will produce two hypocotyls. However, Heinricher (1915) and Weir (1914) observed formations of double hypocotyls in the species of *Arceuthobium* which they studied.

TABLE 1. ABNORMAL SEEDS OF ARCEUTHOBIMUM VAGINATUM
F. CRYPTOPODUM FROM VARIOUS LOCALITIES.

LOCALITY	SEEDS EXAMINED NUMBER	ABNORMAL PERCENT
Sandia Mountains, New Mexico	500	2.4
Manzano Mountains, New Mexico	925	1.7
Flagstaff, Arizona	3,950	0.8
Roosevelt National Forest, Colorado	772	0.7
TOTALS	6,147	1.0

DISCUSSION

The formation of two seeds in the fruit of *Arceuthobium* has the advantage of increased reproductive capacity. However, this is presumably accompanied by decreased efficiency of the seed dispersal mechanism.

Polyembryony is common in the Loranthaceae. Its possible significance in the dioecious mistletoes is discussed by Allard (1943). He suggests that male and female plants may arise from different embryos within a seed. If this is true, it is possible that a mistletoe population could develop in a new area from a single seed.

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